Original Article

Can farmers reliably perform neonatal lamb post mortems and use the results to influence their behaviours?

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Abstract

Neonatal lamb mortality constitutes a significant economic cost and is an important welfare challenge. Despite compelling evidence for reduction strategies and cost benefits associated with it, there has been no documented trend in national reduction since the 1970's. We aimed to evaluate whether a knowledge exchange solution can be accurately used to define farm specific loss risks by training farmers how to examine neonatal lambs post-mortem and follow a basic framework to record and interpret common causes of mortality. Finally, we used participatory rural appraisal to assess some of the existing challenges to reducing lamb mortality. When considering outcomes for specific post mortem questions, there was 87.5% agreement between veterinary and farmer answers and 82.3% of farmer diagnoses (*n*=96) agreed with the veterinary conclusions. When merged with farmer performed post-mortems, farm specific mortality pie-charts were developed to highlight the variation between flocks and the necessity for flock specific advice. Common challenges to reducing loss included level of labour, skill set of labour, communication within teams and shepherds generally considered post-mortems to be a valuable tool. We consider that farmer PMs of lambs could be a tool for the veterinary-farmer team, facilitating the communication of farm specific advice and empowering farmers to effect positive change.

Keywords

Knowledge exchange

Lamb mortality

Post-mortem

Farmer

Introduction

Neonatal lamb mortality constitutes a significant economic cost, an obstacle to achieving efficient and sustainable lamb production and is an important welfare challenge (Binns *et al.*, 2002; Sawalha *et al.,* 2007; Dwyer, 2008).

Neonatal lamb mortality is defined as the death of lambs during the first week of life with the predominant risk period being the first 48 hours. Overall lamb mortality between scanning and sale ranges from 10-25% (Mellor and Stafford, 2004) but in the authors experience, it can as high as 30-40% on some farms. Typically 5.9-12.5% of scanned lambs are lost between 0-48 hours old (Binns *et al.*, 2002). Key causes of neonatal lamb mortality include stillbirth, hypoxia due to dystocia, starvation, hypothermia, injury secondary to dystocia or mismothering, infectious disease such as watery mouth (Dwyer, 2008).

Risk factors leading to these causes of deaths include low birth weight, high birth weight, poor maternal body condition, lamb vigour at birth, underlying deficiency i.e. selenium or iodine, dystocia, ewe with poor mothering ability, poor hygiene (Mellor and Stafford, 2004). Multi-level modelling has identified farm and management risk factors which are linked to increased level in lamb mortality such as outdoor lambing, less frequent renewal of bedding in pens, larger flocks and flocks with higher replacement rates. Factors such as housing ewes and supplementing thin ewes were found to be protective (Binns *et al.*, 2002). Experience of the

shepherd, feeding frequency, suckling assistance provided and use of lambing pens were found to be protective in an additional model (Holmoy *et al.,* 2012).

Targets for lamb mortality for a lowland flock should be less than 14% between scanning and sale, made up of 6% from scanning to birth, 6% from birth to turnout and 2% from turnout to sale (EBLEX Manual, 2015).

In 2014 within a large farm animal practice in South West England, a lamb mortality survey of commercial flocks measured total lamb mortality between scanning and weaning, with the practice median recorded as 10.4% (*n*=30, range= 4.4%-20.8%) (EG personal communication). Losses before turnout i.e. including pre-lambing and peri-lambing mortality represented the largest loss period in most flocks. Few flocks could attribute causes of loss to those lambs not surviving to weaning through their pre-existing recording methods.

The variation in lamb losses demonstrated both in peer reviewed literature and in commercial flocks in this practice-based survey, highlights that low levels of lamb loss are achievable, but despite this and mounting evidence of causes of lamb mortality, compelling evidence for reduction strategies and cost benefits associated with it, there has been no documented trend in national reduction in the past 40 years (Dwyer *et al.,* 2016).

Possible reasons cited for this lack of reduction are suggested in the literature to be (a) lack of farm specific solutions, (b) dismissal of research results by commercial farmers due to use of non-commercial flocks in studies, (c) difficulty in applying the evidence base to commercial flocks given the complex nature of mortality or finally (d) lack of communication of the evidence base by advisors to the farmers (Dwyer *et al.,* 2016).

This work also suggested that farmers felt 'powerless' to effect change and reduce losses within the 48 hours of life in lambs and prefer to divert resources to latter stages of production where their efforts may be perceived as more effective (Dwyer *et al.,* 2016). Other challenges to loss reduction could be perceived size of investment in labour and resource necessary to reduce losses and lack of perception of the pre-existing scale and cost of lamb mortality to a sheep business.

The variation in losses observed in the 2014 practice based survey suggested that generic lamb mortality advice has limited value when applying to sheep flocks, given (a) the range in diverse systems and (b) the diversity in main causes and timings of lamb losses. For example, not all flocks examined experienced peak lamb loss in the neonatal period and with post-turnout losses more significant for some flocks.

Data collection on farm or lack thereof is often cited as a challenge for quantifying level of and causation of lamb mortality at all stages of production. The practice survey examined scanning and

movement record data to compare potential lambs available for sale and actual number sold or retained within the flock. Mid production cycle figures such as first numbers at first gather may enable crude assessment of specific phases of loss, but suspected cause of death is often challenging to obtain from flocks unless there is pre-existing farmer motivation to record. Furthermore, in our experience, unless there is a substantial increase in the level of morbidity and mortality in lambs, veterinary surgeons are rarely asked to routinely examine neonatal lambs post-mortem, presumably because of (a) cost, (b) logistics and time of taking lambs to a collection centre and/or (c) lack of perceived benefit.

We hypothesised that equipping sheep farmers with skills and resources to enable them to define the specific causes of neonatal mortality on their own units can lead to engagement and empowerment of sheep farmers to effect change and appropriate targeting of advice by their advisor and channelling of resources to reducing neonatal mortality.

The objectives of this study were:

1. To evaluate whether a knowledge exchange solution can be accurately used to define loss risks by training farmers how to examine neonatal lambs post-mortem and follow a basic framework to record common causes of mortality
2. To work with farmers and using the results to build up a farm specific picture of causes of mortality

3. To enable farmers to use this evidence to make changes that reduce the risk leading to avoidance lamb mortality.

We measured our success in achieving these objectives by answering the following questions:

a) Once trained by a veterinary surgeon, can sheep farmers accurately diagnose common causes of mortality in neonatal lambs?
b) What were the common causes of lamb loss on each farm and how did these differ between units?
c) Did the farmers involved in the project use their findings to effect change?
d) How has the programme changed attitudes and motivation?

Materials and methods

Flocks

Five flocks were recruited to participate in the project. The flocks were convenience selected based on an expressed interest by the shepherds to target lamb morality as one of their annual key performance indicators, proximity to a central veterinary practice (within 40 miles of Synergy Farm Health Ltd), defining themselves as commercial sheep flocks i.e. lamb sales were a significant portion of farm revenue and lambing in Springtime. Four of the flocks were within Dorset and the fifth was in Somerset.

Ewe numbers in the flocks ranged from 250-2500 with a range of breeds and systems i.e. entirely outdoor lambing Romney flocks, indoor/outdoor composite units based on Mules with twins outdoors, triplets and singles indoors to facilitate wet fostering and finally, entirely indoor lambing units lambing Lleyns (see table 1).The flocks were visited between three and six times over lambing depending on their duration and peaks in lambing.

Study design

The five shepherds participated in a one day practical course delivered by veterinary surgeon investigator and one of the authors (EG) who has recognised training qualifications (Foundation Certificate in Staff Development and Certificate in Training & Occupational Learning). The farmer training course covered the background to lamb mortality including its common causes and financial implication, common zoonotic challenges when working with lambing sheep and relevant additional health and safety risks associated with performing a post-mortem (PM) examination of peri-natal lambs i.e. pre-natal abortions or post-natal losses. Control of Substances Hazardous to Health (COSHH) datasheets were presented for recommended disinfectants.

The importance of sample selection was also explained to participants with farmers recommended PM animals with a known clinical history and less than 24 hours deceased. Disposal of carcasses via approved routes i.e. via fallen stock for incineration was recommended. The farmers also took part in a practical session

206 at a local fallen stock yard (Secanim Ltd, Dorset) where PM
207 techniques were demonstrated on fresh samples and the shepherds
208 examined further lambs whilst being supervised. The framework for
209 PMs used was an adapted version of a lamb PM form (AHDB Beef
210 and Lamb; see supplementary material).

211 The flocks were then visited weekly throughout lambing up to a
212 maximum of six visits and a single investigator (EG) observed farmer
213 performed PMs on lambs which had died within the previous 24
214 hours. Both the shepherd and EG completed their PM form in
215 isolation with results discussed after form submission. These results
216 were collated and compared and submitted into Microsoft Excel
217 2013. The data was checked for errors and then univariate binary
218 analysis was performed in R (R Core Team, 2013) with the
219 significance level set at $p<0.05$.

220 Shepherds were also asked to perform PMs on lamb in the interval
221 between veterinary visits with the results submitted to the project.

222 After initial analysis of comparative PMs, the veterinary causes of
223 death were combined from "comparison PMs" were combined with
224 the farmer performed PMs (completed in absence of vet between
225 visits) to produce a farm specific pie chart for cause of death.

226 *Participatory Rural Appraisal*

227 Dwyer *et al.,* 2016 considered the obstacles to effecting change in
228 reduction of lamb mortality on farm. Participatory Rural Appraisal
229 (PRA) is a recognised approach using systematic and structured

activities to gain understanding of rural resources and attitudes from the local people (FAO website, Chambers, 1994). It has been used extensively in the developing world by non-government organisations (NGOs) to facilitate delivery of targeted, effective and realistic solutions to local people. PRA by definition is designed to be a flexible interviewing and engagement exercise designed to empower individuals who are likely to effect change, with the aim of arriving at sustainable local actions. Semi-structured interviews (SSIs) are often used to facilitate this (Grandstaff and Grandstaff, 1987, van Teijlingen, 2014). A single investigator (EG) facilitated the SSIs which were recorded and ranged from 30 minutes to 2 hours.

During the SSI, the shepherds were asked to participate in a series of exercises relevant to lamb mortality:

(a) To write a list of the tasks necessary on a typical day during lambing
(b) To place dried beans next to the jobs they felt took the most time.
(c) To rearrange the beans and place then next to the jobs that they felt kept the most lambs alive. This list was also photographed (see figure 1).

They were also questioned during the SSI about their attitudes towards PMs, the challenges for lamb mortality on their own farms and how PMs had influenced practices on farm. Finally, they were asked to rank risks for lamb mortality on their own farm on sliding

scales of 0-10 i.e. 0 no threat to lambs on the unit to 10, a very significant threat to lambs.

Interviews were recorded and transcribed into Microsoft Word 2003. The interviews were analysed using thematic analysis techniques with the transcripts coded, unitized for common concepts and then compared using the constant comparative technique (Maykut and Morehouse, 2001).

Results

Quantitative analysis

A total of 96 lambs were examined by PM across five flocks in the presence of the investigator and an additional 40 lambs examined by farmers directly.

From this table we can see both variation between questions and variation within questions between farmers. When considering specific questions, correct answers per question ranged from 80.2% of answers given up to 97.9% agreement with the veterinary surgeon. Overall, farmers gave 87.5% correct answers to the PM questions.

When considering farmer answers to specific questions there was a high degree of correlation between vet and farmer answers. Noticeably lower correlation values included for flock A agreement with the vet in 72.3% of cases when considering how many lambs had renal fat present and for flock B with agreement of just 71.4% of

277 answers with the vet when asked if there was evidence of fluid in
278 tissues around the head.

279 When considering all the questions answered, farmers' overall
280 scores all ranged from88.9% of correct answers up to 96.8%.

281 Ultimate diagnosis and the individual farmer results were
282 considered and are presented in table 3, showing that overall, 82.3%
283 of farmer post-mortems agreed with the veterinary conclusion. One
284 flock achieved 100% of correct diagnosis but there were a small
285 number of comparative PMs performed on this farm.

286 When looking at type of diagnoses reached, the proportion of
287 correct diagnosis were classified relative to the veterinary confirmed
288 cause of diagnosis (see figure 2). We can see that the largest errors
289 were made when the veterinary verdict was "no diagnosis" (*n*=16
290 total) and "starved" (*n*=21 total).

291 *Common causes of mortality*

292 Given the level of agreement between vet and farmer diagnosis, a
293 pie chart was generated for each flock showing common causes of
294 death. (See figures 3a, b, c, d, and e) and presented to flocks during
295 their semi-structured interviews.

296 *Qualitative analysis*

297 After transcription of the semi-structured interviews, they were
298 coded according to key themes identified during transcription. Key
299 themes identified when considering lamb mortality were: (1)

responsibilities during lambing (2) provision of skilled labour (3) team dynamics (4) the advantages of PM examination on farm (5) the challenges of PM examination on farm (6) changes made as a result of PMs.

The responsibilities of lambing

When shepherds were asked to list their task lists during a typical lambing day, there was huge variation between flock types and additional enterprises/responsibilities on farm. Having initially been asked to rank tasks based on their duration, they were then asked to revise the ranking based on how important the relevant task was in keeping lambs alive. This revision highlighted for flocks (a) time-consuming jobs which did help keep lambs alive i.e. teaching students, checking colostrum status, feeding ewes (b) time consuming jobs which did not help keep lambs alive and i.e. tagging and recording lambs, checking cattle (c) jobs not currently consuming a lot of time but which could help keep lambs alive, for example treatment of pre-parturient lame ewes in the lambing shed. Typical statements included:

> "In my role we are also talking about coordination of contractors at that time of year we are trying to get corn in the ground."

> "Did we put enough labour to it? There was a lot of stock about. We still had fat

hoggs about which needed drawing for abattoir. Should we get to the point of having minimal stock at Spring?"

"It's surprising how long the dogs take!"

The role of colostrum management in reducing lamb mortality was repeated in multiple interviews. The importance of colostrum management and diagnosis of starvation and mismanagement was also coupled with the importance of stockmanship:

"I check the colostrum of every lamb, but you've got to be able to spot how a lamb behave and moves too".

The desire to have more lambs reared was communicated by all flocks as a key driver of improving margins per ewe. However, how to achieve this divided opinion, for example when considering whether emphasis should be placed on increasing scanning or increasing rearing percentage:

"No I am happy with scanning but I would like to think 1.75 should be doing better than that, lots claim can scan higher. I know that's not desirable because you end up with lots of triplets and I am not wanting that but, I want to be producing lambs and not keeping sheep for the fun

on it. The way forward is using our building and resources to the best of its ability".

The drain of time resources that small lambs place on the shepherds was observed and discussed in all systems. They were considered to be unrewarding and where possible, flock health planning and fertility management should be used to avoid small lambs.

"The problem with triplets is every single one needs assistance. It's not like twins".

"Breeding these small lambs is a wastage, it's a wastage of time and resources put into them!"

Provision of skilled labour

Provision of skilled labour and staffing levels was discussed in all five interviews irrespective of indoor or outdoor lambing models.

The role of less experienced veterinary or agricultural students in the lambing sheds was evident from all interviews. However, this leads to challenges that may have contributed to lamb mortality.

"It is frustrating in some cases [student labour] might be a help, because you have those pair of eye, or you have people who feed individual pens. You know, I send people around to check pens, to get sheep up, get lambs up, check they are all ok,

check mouths, just occasionally they might miss something, so you are relying on people who are training to learn, and part of their learning is that they are going to make mistakes that you are going to have to correct which can be to your detriment!"

Availability of skilled relief during lambing was discussed by multiple shepherds as was the challenge of delegating jobs which required an inherent skill and stockmanship level. The lack of such relief either through lack of recruitment to the team or availability in the job market, put pressure on shepherds wishing to delegate aspects of their responsibility lists. Phrases such as 'not for a novice', and 'it's not the sort of thing I could just get Joe Bloggs to do' were used.

When asked whether student teaching does save lambs, several participants agreed that it did due to increasing skill levels in those individuals enabling them to facilitate lamb management:

"Communicating to student sometimes does keep lambs alive. I think that's where I am not spending enough time".

In general flocks were however sympathetic to the educational needs of students and the role they play in their systems:

"I always say you learn by making mistakes but by seeing good things as well".

However, an interesting counter-argument presented when discussing levels of supervision and the possibility of over-supervision:

> "Well you could argue is too much supervision *chuckles* just lots of disturbance, not like a normal farm- we have kids running around pens, I am trying to think what to call it, unskilled supervision."

Team dynamics

The challenges of team communication during lambing was a common theme in all five interviews and ranged from mismatched input expectations between managers and assistants to individual participants' frustration with the lambing period if lambs died during assisted lambing.

The importance of a team strategy prior to lambing was acknowledged by managers:

> "My intentions were that full time staff were going to have a sit down and structured talk about what we wanted and what we wanted to achieve and that was important and it didn't happen."

> "I think communication within a big team who might be around when things are

418 happening [is important]. They are
419 constantly being told. It's the starved ones
420 from me which are quite annoying for
421 me!"

422 It was evidence that the aforementioned availability and skill level of
423 relief labour was often an obstacle when shepherds were trying to
424 achieve targets as was incomplete communication of protocols and
425 expectations within lambing teams.

426 *The advantages of PM examination*

427 On the whole the flocks perceived that there was a value in on farm,
428 farmer delivered PMs generating dynamic information in the midst
429 of mortality threats on farm. There was a consensus between flocks
430 that the knowledge gained by performing PMs could contribute
431 towards improving conditions for lambs. A typical response
432 included:

433 "Well I suppose in a way, post morteming
434 lambs, doesn't keep them alive. Well does
435 it? Because we are learning about things,
436 learning about what's killing them!"

437 "You could argue that if you did a few
438 more post mortems if might show you
439 what your problems are which are creating
440 your problems during the day".

The value of PMs as an educational tool for use within teams of shepherding staff and as a visual tool to demonstrate relevance of protocols such as feeding hungry lambs that could be used as an anonymous tool. Finally, its role as a teaching tool for younger inexperienced shepherds was suggested.

The challenges of PM examination

Typical obstacles to conducting PMs were time availability. Flocks were asked about typical time taken to perform a lamb PM on farm. This varied between flocks but ranged between 4-20 minutes. One commented:

> "You do get to a point, where to start with I was being quite neat but you get to a point where you cut it open and have a look and then having a think!"

However, an additional consensus was that if often featured lowly in the priorities of the daily 'jobs lists' despite the apparent value of the additional information:

> "Everything had to come before, all stuff that needing saving"

Furthermore, there was often a desire by flocks to fit in more PMs but finding time was often challenging:

462 “And then there were often times when I
463 wanted to but sometimes a couple of days
464 went by”.

465 “The actual physical 30-20 minutes but all
466 of a sudden you have people coming in
467 saying ‘Can you come and help me?’ and
468 then I haven’t [got time]!”

469 *Changes made*

470 Flocks commented that they had made changes to management
471 based on results found doing PMs on farm:

472 “Anything we changed this year? The
473 biggest single change was having the lamb
474 milk machine going and orphan lambing
475 coming own to either the hot boxed or
476 under the lamps….. there was lot more
477 input directed at orphan lambs this year!”

478 One flock experienced an infectious lameness outbreak in housed
479 ewes with contagious ovine digital dermatitis (CODD). When
480 discussing their PM results and risk for lamb mortality on their own
481 unit, lameness management was a central theme in the discussion.
482 When asked if infectious lameness management has a positive
483 effect on lamb mortality diagnosed on their farm the impact on ewe
484 health and welfare and subsequent lamb survival was discussed:

Participant 1: “Yes it does a bit doesn’t it, because they produce more milk!”

Participant 2: “Well why didn’t we have any beans on there before we started?” (*Referring to time expenditure in initial exercise)*

There were scenarios where despite evidence from the PMs, additional inputs were not possible. For example when asked about how the PM results could be used to influence management practices next year, the responses were:

“We could look around more, but I’d never stop. Ideally we’d employ and extra person but there is a cost!”

“But it is also having a system which allows minimal input and minimal labour to help a lot of sheep that’s the design of the system, watching ewes, pens and turning out, and feeding obviously.”

Whilst dynamic information did enable flocks to monitor ongoing and changing threats to lamb mortality, there was a situation where there may have been over interpretation of results. When asked what was changed as a result of accumulating data:

507 "And one of the things we changed more
508 this year, was we intervened more with
509 lambing, because of what we had seen…"

510

511 Discussion

512 Dwyer *et al.* (2016) identified the challenge for commercial sheep
513 flocks in implementing and effecting change on commercial sheep
514 flocks when considering lamb mortality. The lack of progress
515 reported over the past forty years represents a substantial threat to
516 ongoing animal welfare and the profitability of sheep flocks. To the
517 authors' knowledge, this is the first study on sheep farms to explore
518 farmer's beliefs about the limitations of their own system and likely
519 effects of change, (although other examples exist in other fields
520 such as bovine lameness (Main *et al.* 2012)) and represents a novel
521 knowledge transfer based solution to the investigation of lamb
522 mortality.

523 Our main objective was to assess the reliability of farmer PM results
524 by comparing anonymous farmer and veterinary surgeon
525 completion of a PM report when observing the same lamb.
526 Challenges in obtaining this data included availability of suitable
527 carcasses on dates of visits i.e. due to lack of carcasses, lack of
528 availability of fresh carcasses or predation of outdoor lambs.
529 Additionallyfarmers commented in the SSI that they had found
530 limited time opportunities during lambing to perform lamb PMs and

had placed more emphasis on 'living lambs' although they recognised the value of the information obtained by PM. In the authors' opinion, as many lambs as possible should be examined by post-mortem as possible in order for results to accurately reflect the risks to lambs on farm. Other authors have suggested that 10% of neonatal lamb losses should be examined by post-mortem (Fragkou *et al.,* 2010).

When performing comparative PMs, farmers often queried outcomes or unusual presentations after submission of individual PM reports and therefore there is likely to be a contribution of this continued knowledge exchange throughout the project in comparison to the situation where farmers are not routinely visited by a veterinarian through the lambing period. The effect of this cannot be easily quantified due to small numbers of PMs and the variation of presentations at each visit.

Signalment, accurate weights and history of dead lambs was not considered in our analysis and was often absent on the farmer-derived PM reports accumulated in the absence of a vet. Many preferred to include small, medium or large when assessing lamb size. In our opinion this does not negate the value of the PMs but may limit the accurate assessment of pathogenies of lesions, for example where no age at death is available for a lamb that died as a result of neonatal scouring. Likewise, it may limit interpretation of the success of interventions.

When examining farmer accuracy in answer specific questions about an individual lamb, they were largely consistent and successful (see table 3). Some parameters proved more challenging than others and in our opinion the subjective nature of some questions led to these errors. For example meconium staining was the subject of debate and its relevance for ultimate diagnosis is not apparent. Secondly there were disagreements on presence and absence of peri-renal fat (see figure 4). This brown fat is typically considered to have disappeared within 6 hours of birth but there were older lambs where this was still apparent. As a consequence, some farmers may have been dissuaded from concluding that starvation was the cause of death, especially where time of death had not been recorded. This may account for the errors observed in this diagnosis category (see figure 2).

The largest proportion of errors occurred when examining the navel for evidence of dryness which is not likely to be significant for drawing ultimate diagnoses. However, missing the evidence of broken ribs and clots is likely to skew diagnosis (see figure 5 showing free blood in abdomen secondary to liver rupture, figure 6 showing broken ribs).

The disagreements between lungs floating and not, in the investigators' opinion, is likely to be a recording-related error rather than misinterpretation. The phrasing of the question on the original and adapted questionnaire is ambiguous and would need to be

revised before making available to farmers for ongoing recording purposes.

When considering final diagnosis, 82.3% of farmer PMs reached the same diagnosis as the veterinary surgeon and individual farmers ranged from 79.2-100% correct. It should be noted that the farmer achieving 100% did the smallest number of post-mortems. The largest errors were in “no diagnosis” i.e. where farmers stated a cause of death but the veterinary surgeon did not think that one was apparent, and secondly for ‘starvation’. High errors in assessing remaining brown fat levels may account for flocks failing to treat starved lambs. In our opinion the farmers were successful in diagnosing cause of death in lambs but that ongoing validation is necessary to ensure common diagnoses are not being overlooked.

Our second objective was to evaluate common causes of death in neonatal lambs and to observe how these varied between different units. This was achieved by merging the veterinary diagnoses from joint PMs and farmer diagnoses from PMs performed without supervision. The combined results reflect previous PM work in the UK (Green and Morgan, 1993) with common diagnoses featuring such as ruptured liver, broken ribs and “hung lambs” with oedema of the neck having presented with an anterior, dorsal presentation with no forward presented legs. We can see clearly in figure 3 that there is significant variation in cause of lamb deaths between indoor and outdoor units. There is also variation in causes of death

604 between similar units i.e. the two indoor lambing flocks with
605 traumatic injuries such as broken ribs and ruptured livers more
606 significant in flock A than flock E. The infectious disease profile e.g.
607 presence of watery mouth also varied between units. A clear
608 difference is the significance of starvation for the entirely outdoor
609 lambing flocks in comparison with other systems.

610 This variation in causes of death in lambs between units supports
611 previous suggestions that generic lamb mortality advice is not
612 appropriate for flocks (Dwyer *et al.,* 2016). For composite flocks i.e.
613 indoor and outdoor lambing, it was not possible to establish
614 whether lambs were indoor and outdoor in origin and therefore it is
615 likely that both contribute to the flock pie charts. We suggest that
616 when focusing specific investigations, origins of the lamb is essential
617 information for such flocks and should be recorded.

618 Our third objective was to consider whether results obtained could
619 be used to effect change on participating flocks and to consider
620 owner attitudes and motivations for change. When asking farmers
621 to comment on the combined diagnosis during the semi-structured
622 interviews, resource availability both for (a) fitting in PMs or (b)
623 implementing change, was often a limiting factor and varied
624 between farms. This supports Dwyer *et al.* (2016) emphasis on the
625 importance of flock specific advice based on known farm specific
626 risks.

627 When considering changes made during lambing or to be made for
628 subsequent years, one flock acknowledged that investment in

629 additional labour could reduce their lamb mortality. The role of
630 students in lambing systems was evident and there was
631 acknowledgement of the importance of investing time in training
632 individuals and the benefit they could have in reducing lamb
633 mortality. Many flocks find it challenging that students often arrive
634 on farm at the commencement of the lambing period and leave at
635 the time they have developed necessary stockmanship skills. As a
636 consequence one flock involved was considering hiring a relief
637 shepherd/night lamber during lambing to facilitate improved
638 supervision and availability for student training.

639 Whilst we were largely satisfied that farmers had correctly
640 diagnosed and interpreted causes of lamb death, we did observe
641 some misinterpretation. One flock recorded multiple lambs with
642 broken ribs and/or liver capsule rupture. As a consequence they
643 opted to intervene more quickly when ewes were lambing, but did
644 not observe a reduction in the presence of pathology. On debriefing,
645 we were concerned that these lambs were being assisted before
646 ewes had had sufficient opportunity to dilate (especially where large
647 single lambs or backwards lambs) and that the preferred action
648 would have been to observe ewes and give them longer prior to
649 intervention with strict standard operating procedures for when and
650 how to intervene. As a consequence of this debrief, such operating
651 procedures are in place for the next lambing. However this
652 highlights the importance that farmer-performed lamb PMs are not
653 used in isolation without technical support and advice from the
654 flock's routine veterinary surgeon.

We consider that, in conjunction with appropriate supportive advice, that PMs could form a tool for veterinary engagement through training, ongoing support and flock health planning to empower flocks in generating their own reliable, farm specific data. A basic understanding of common causes of lamb mortality such as starvation will enable farmers to have an immediate impact on operating procedures on farm.

It should be acknowledged that this this study only examined five flocks with moderate-high veterinary engagement and a pre-existing commitment to reducing lamb mortality. However, it could be considered a novel strategy for flock engagement and mortality investigation.

Conclusions

The role of the veterinary surgeon in sheep enterprises is dynamic and evolving especially with the movement towards flock health and production management. As observed in other areas of farm animal medicine, we must embrace our diverse role as vets and consider what alternative inputs we can have on farm i.e. though training and dynamic interaction with farms.

Veterinary surgeons should not be threatened by this involvement of farmers in the decision tree as is currently embraced in many other aspects of farm animal practice given the lack of protection conferred by the Veterinary Surgeons Act over roles previously

considered the remit of veterinary surgeons alone. For many veterinarians engagement in large numbers of lamb post-mortems in not a reality and pre-existing pro-forma decision trees are available in the public domain (AHDB, 2016). This should be seen as an opportunity for engagement in training and with producers.

We consider that farmer PMs of lambs could be a tool for the veterinary-farmer team, facilitating the communication of farm specific advice and empowering farmers to effect positive change.

Conflict of interest

The authors declare they have no competing interests.

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749 Captions

750 Table 1: A summary of the flocks recruited to the project including
751 breeds on farms.

752 Table 2: A table showing the proportion of correct answers by flock
753 to post-mortem specific questions when considering comparative
754 post-mortem examinations.

755 Table 3: A table to show the percentage agreement in diagnosis
756 between farmers and vet observing the same post-mortem

757 Figure 1: An image showing a section of a farm produced “jobs” list
758 complete with examples of beans assigned to each task type.

759 Figure 2: A graph to show proportion of correct diagnosis from
760 farmers, relative to veterinary diagnoses for each diagnosis type.

761 Figure(s) 3 (a-e): Flock specific pie charts with data merged from
762 farmer-vet comparative PM’s with farmer PM’s. Where comparative
763 PM’s, if farmer and vet disagreed the vet diagnosis was utilised

764 Figure 4: An image showing an example of peri-renal fat present in a
765 neonatal lamb

766 Figure 5: An image showing free blood in the abdomen of a neonatal
767 lamb due to liver capsule rupture.

768 Figure 6: An image showing unilateral broken ribs in a neonatal

769 lamb.

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